SUPPLEMENT TO THE FORTY-FIFTH ANNUAL REPORT OF THE DEPARTMENT OF MARINE AND FISHERIES, FOR THE FISCAL YEAR 1911-12

REPORT ON THE INFLUENCE OF ICEBERGS AND LAND ON THE TEMPERATURE OF THE SEA, AS SHOWN BY THE USE OF THE MICRO-THERMOMETER, ON A TRIP OF THE C. G. S. MONTCALM IN THE GULF OF ST. LAWRENCE AND COAST OF LABRADOR

AND

NOTES OF A TRIP ACROSS THE ATLANTIC ON BOARD THE R. M. S. VICTORIAN, ON WHICH A MICROTHERMOMETER HAD BEEN USED

BY

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PRINTED BY ORDER OF PARLIAMENT

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1913

[No. 21c—1913.]

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To A. Johnston, Esq.,
Deputy Minister of Marine and Fisheries,
Ottawa.

Dear Sir,—I have pleasure in giving you herewith my report on the influence of icebergs and land on the temperature of the sea. I desire at the same time to record my indebtedness to the Minister, Hon. J. D. Hazen, and to yourself for the help which has been given me, without which the work could not have been done.

In my report to the department which described my experiments made in the summer of 1910, on the influence of icebergs on the temperature of the sea, I pointed out the need of more detailed observations for which a special ship was required.

I am deeply indebted to the Minister and yourself for the use of the ice-breaking steamer *Montcalm* during the past summer, and to the officers of the ship for their help in bringing the experiments to a successful conclusion.

The experiments herein recorded were made by means of my new marine thermometer, for the first time described in my previous report to the department.

The present report covers a period of three weeks devoted to a study of the influence of ice and land on the temperature of the sea through the strait of Belle Isle and gulf of St. Lawrence.

The thermometer, for the development of which I am indebted to the generous aid given to be by your department, has proved so satisfactory and reliable that I have called it the microthermometer, which name suitably describes the instrument.

As I pointed out in my previous report, it is necessary to have very precise instruments in order to distinguish the effects produced by ice and land from the other temperature changes in the sea. It is in many ways unfortunate that the *Titanic* disaster has caused a somewhat general impression that this work has been done with a view of exploiting an invention, for so many attempts have been made since the disaster to profit by public sentiment. It has, however, always been my desire to investigate the real effects of ice, and place on a scientific basis a subject that has been so completely ignored by men of science. Such good as may accrue from my experiments in the way of helping navigators to locate ice and land in time of fog will be a sufficient reward, but I wish to point out, in justice to myself, that the *Titanic* disaster has in no way affected the course of the experiments, which had been planned many years ago.

My thanks are due to my assistants, Mr. L. V. King, B.A., and Prof. R. W. Boyle, PhD., who accompanied me on the trip: to my brother, Mr. Wilfred M. Barnes to whose skill the success of the photographs is due, and to my son, Master W. H. Barnes, for help in collecting the samples of sea water for analysis.

Faithfully yours,

H. T. BARNES.

REPORT OF OBSERVATIONS.

During my study of the influence of ice on the temperature of the St. Lawrence river, which was commenced in 1895, I was obliged to make use of exceedingly delicate electrical resistance thermometers in order to measure the small variations of temperature which accompany the formation and disintegration of ice. The result of this investigation, together with an account of the instruments employed, was published in the Transactions of the Royal Society of Canada during the years 1896 and 1897, and in my book, 'Ice Formation,' published by John Wiley & Sons, New York.

It is a source of gratification to me that this work which was commenced purely as a scientific investigation should have proved so useful in directing efforts towards devising methods for overcoming ice trouble in hydraulic power-houses.

It is due to the labours of Mr. John Murphy, of Ottawa, that methods have been devised by means of which artificial heat may be successfully applied for the relief of ice troubles during the winter. The practical advantage gained through this work encouraged me to continue my investigations along the same lines from the Government ice-breaking steamers while at work at the Northumberland strait and at Quebec. My experiments, conducted by means of the generous aid of the Department of Marine and Fisheries, were embodied in a report to the department in 1910 and published in 1911. During this time I devised the microthermometer with which I could obtain automatic records of temperature accurate to thousandths of a degree.

The microthermometer consists essentially of three parts, the stem or bulb, the relay or galvanometer, and the recording mechanism. In the appendix to this report I give a detailed description of the microthermometer for those interested in a study of its operating principles.

Position of the Microthermometer on Board Ship.

The instrument may be held over the side of the ship, trailing in the water and held by means of guy ropes, and the wires brought in to any convenient place to the recorder, or it may be put in a stream from a seacock fed from the intake of the circulating pumps. This latter method is to be preferred in a fast moving ship to avoid excessive strain on the bulb in a rough sea, and chances of damage from floating ice.

The question of the depth to which it is best to immerse the bulb is one which was answered during the course of the experiments described in the present report.

The *Montcalm* was equipped with two thermometers, one trailing alongside at an average depth of a foot, and the other placed in a tank fed continually by water taken at a depth of 16 or 18 feet.

The question of the proper depth for best serivce can be disposed of at once. As a result of the tests it was found (1) that the surface thermometer showed greater variations of sea temperature away from ice than the deep thermometer. (2) It showed a greater change due to land. (3) Practically no difference in its records of icebergs over those from the deep thermomter. It was found on the whole that steadier conditions held on the deep thermometer, and this gave better facilities for observing the disturbing influence of ice and land. While the surface temperature varied more up and down, its average value was very close to the average at a depth of 18 feet.

Equipment of the C.G.S. 'Montcalm.'

For the special tests of the present expedition two bulbs were placed as just described. Each bulb was connected to a recorder so that simultaneous charts could be obtained of the deep and surface temperatures. The recorders were placed in the Marconi room on the boat deck, and the wires were taken to the bulbs in their respective places.

Besides the records of temperature we obtained samples of sea water through the strait in order to see how far the fresh water from the melting of the ice affected the salinity of the sea.

Melting of Icebergs.

In my previous report I pointed out how by the theory of Pettersson, ice melting in salt water produced three currents: a cold salt water current, (1), fig. 1 which sinks by gravity downwards: a horizontal current (2) of warm salt water moving in towards the berg to melt it away: a surface current (3), of melted berg water which on account of its low density flows up towards the surface and spreads out over the sea surface.

Observation of old icebergs gives abundant evidence of the action of the melting under the water line corresponding to current 2. The photograph shown in fig. 2 illustrates the action of the sea surface in eating away the under side of the ice. Fig. 3 shows the opposite side of the same berg. Surface melting, and the action of rain is shown by the surface furrows. Fig. 4 shows the under part of a berg lifted out of the water by tilting. The furrow made by the warm surface water is well shown. This berg was full of sand and stones as shown by the striated appearance. Fig. 5 shows a berg which has been so melted away that its sides have broken away.

Fig. 6 is a remarkable photograph taken of an iceberg in the Strait of Belle Isle. Here is evidence of much melting. It illustrates the fantastic shapes often seen in ice. The representation of a sleeping wolf is perfectly shown.

The question of the existence of the surface current (3) of fresh water must now be regarded as not proven, but it is possible that a berg does dilute the sea water to a very small extent over a small area. The melting proceeds at such a slow rate, especially in the northern waters, that the surface water from the melting berg becomes mixed rapidly with the sea water.

Preliminary Observations of the Iceberg Effect.

In July, 1910, the department kindly placed at my disposal a berth to Hudson strait and bay by the C.G.S. *Stanley*. I equipped the steamer with a recording microthermometer and sent my assistant Mr. L. V. King, to look after the instruments and make observations. A report of this work was published by the department, which report contains the charts made on the trip.

The thermometer bulb was placed over the side of the ship and immersed to a depth of about five feet. The recorder was placed in Mr. King's cabin where he could observe the effect of ice and land.

Several icebergs were passed on the northward journey at a distance of from one half to a quarter of a mile. These were shown on the chart, first by a rise of temperature followed by a fall of temperature as the ship passed abeam of the berg. The rise of temperature was unmistakable and was quite unexpected. Yet it was so evidently a result of the influence of the ice that special attention was directed to it. In my report on these tests I was unable to offer a suitable explanation, but it is possible now to suggest the real nature of the effect.

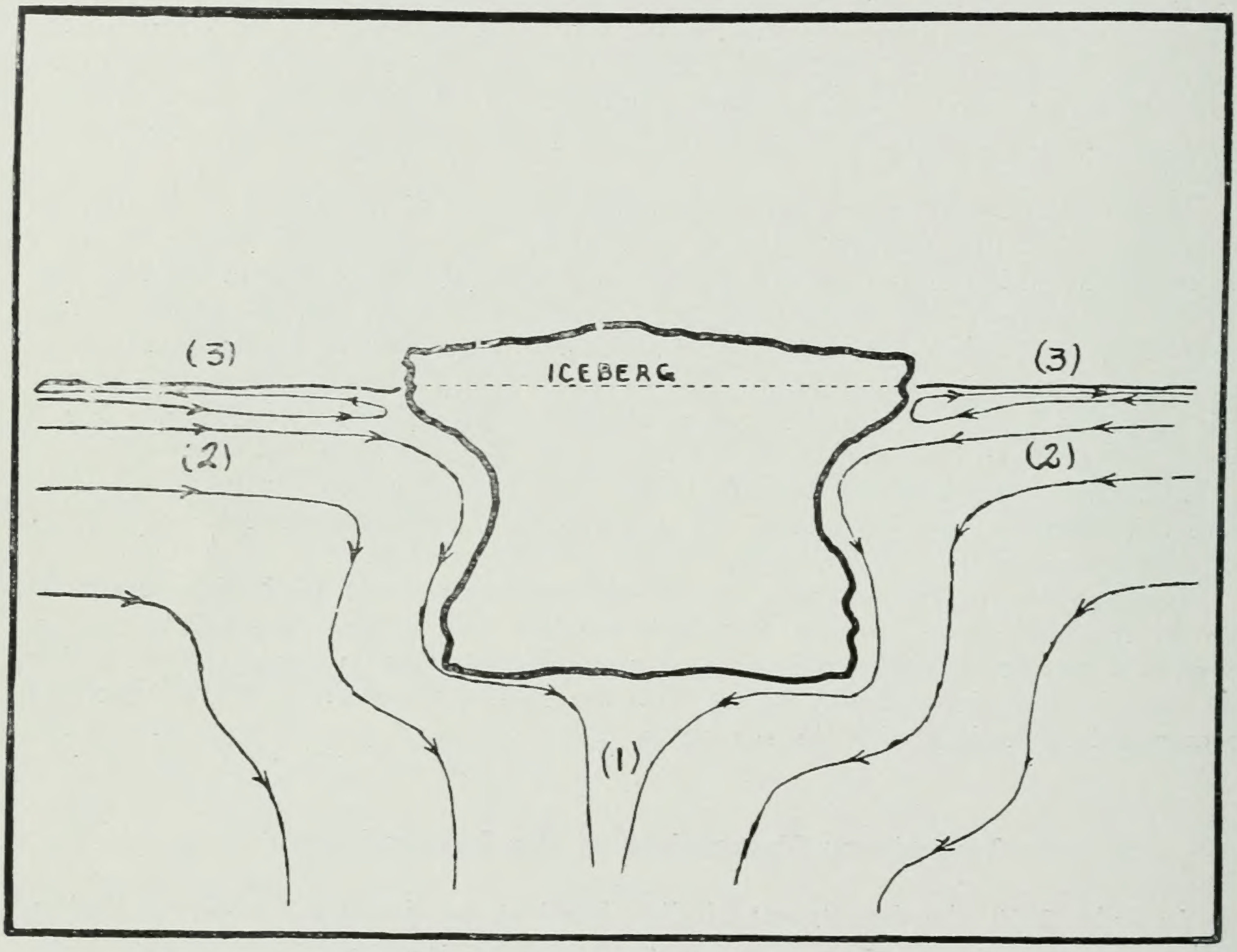


Fig. 1. Ice melting in salt water.

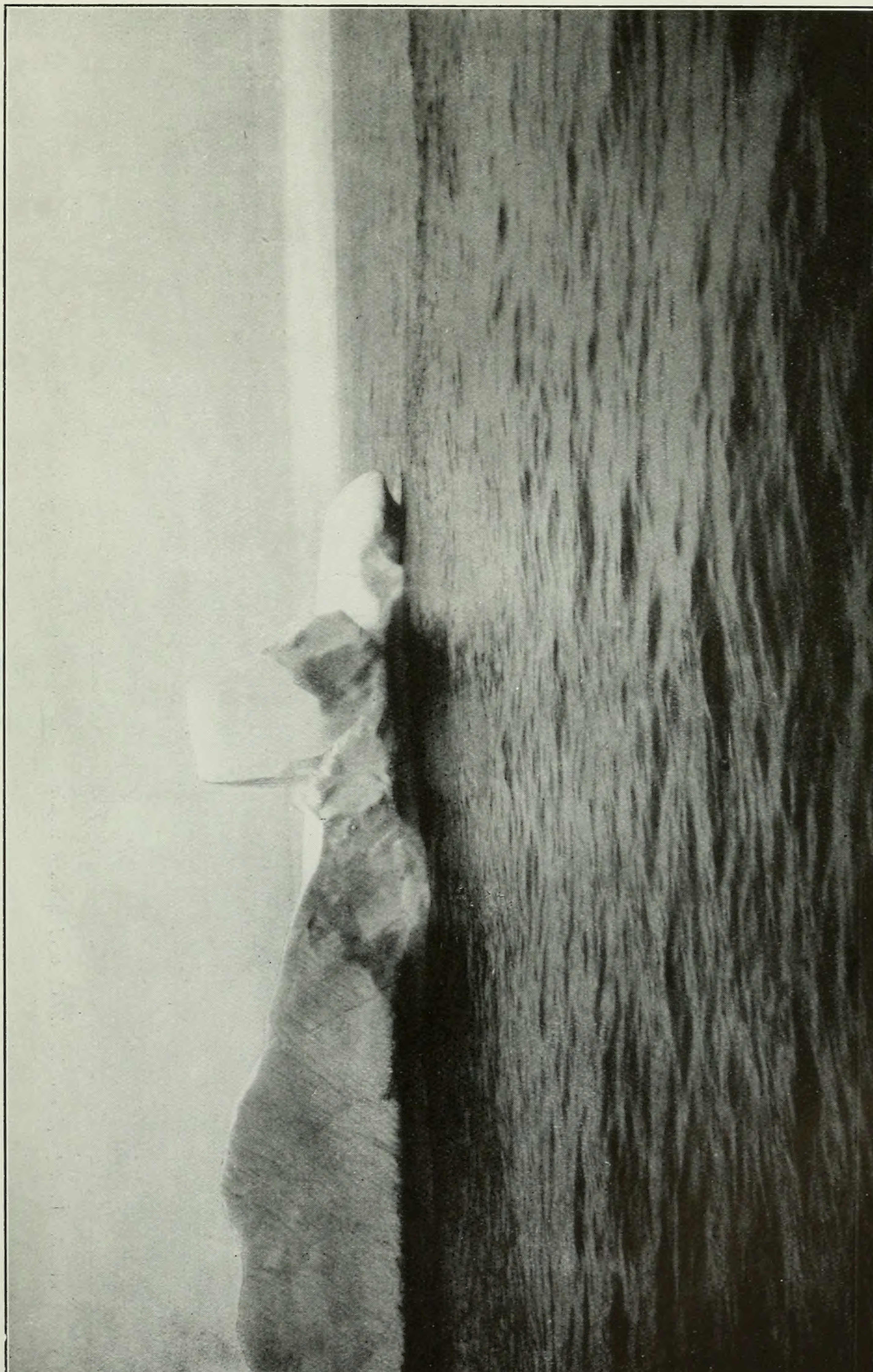


Fig. 2. Photograph showing the effect of sea water melting on an iceberg.

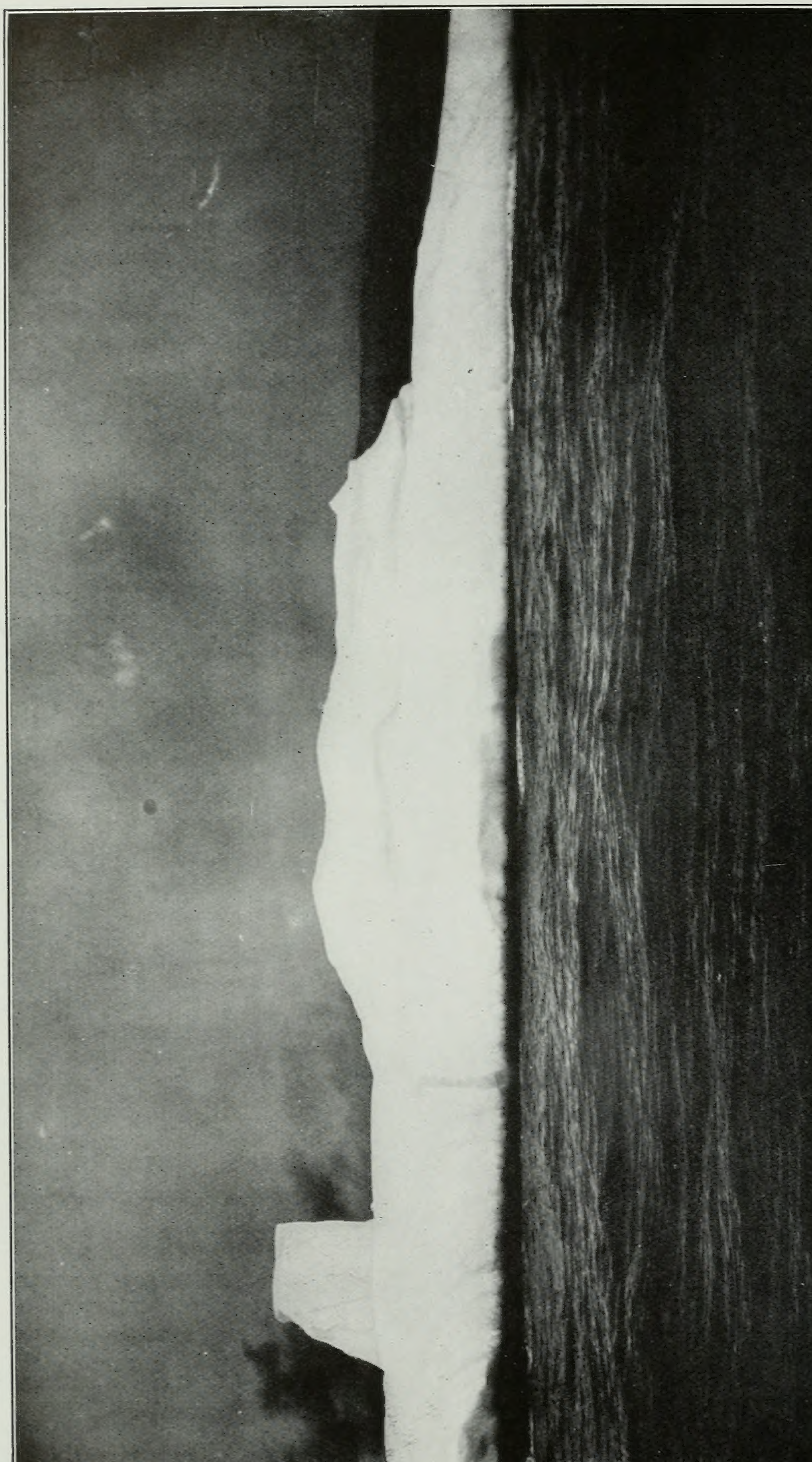


Fig. 3. Photograph showing the effect of seawater melting. Observe the contrast between the white ice and the dark absorbing water.

Fig. 4 This iceberg shows the underwater melting which has gone on before it tilted over. The ice is full of dark lines consisting of sand and dirt. Many large stones were observed over the surface.

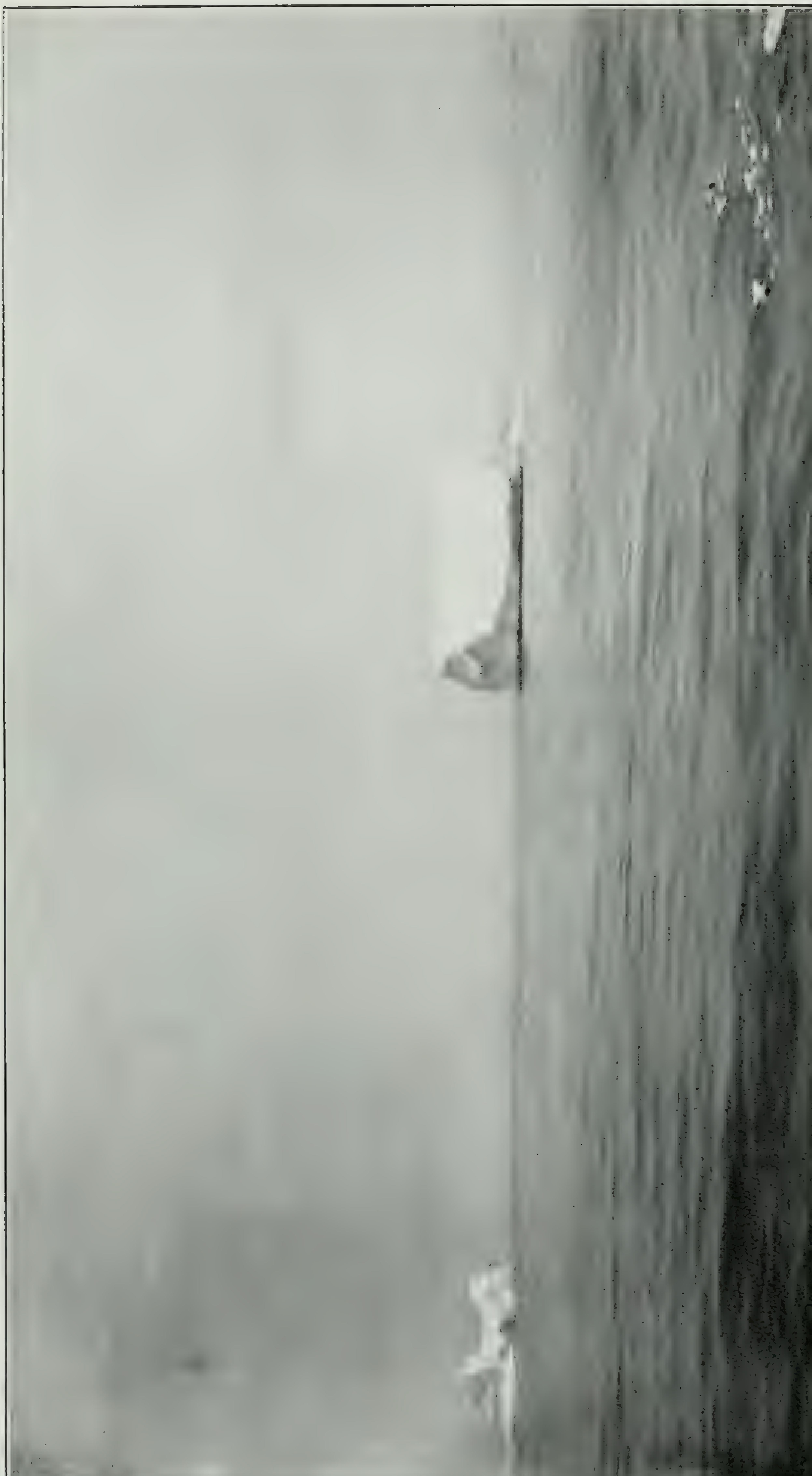


Fig. 5. The iceberg to the right shows the action of the underwater melting which has caused the sides to fall away. This berg has probably never turned over. The berg to the left shows the effect of turning over.

Fig. 6. This iceberg shows the fantastic shapes caused by underwater melting. The head of a sleeping wolf is shown.

The iceberg effect, as I called it, consisted of a rise of temperature as the berg was approached, followed by a rapid fall of temperature. There is little room to doubt that the real iceberg effect is the *rise of temperature,* and that the fall of temperature observed by Mr. King is due to the influence of the colder current in which the iceberg is being carried. My latest observations described in this report show that this must be the case, for the icebergs studied and described here, all carefully observed, showed a large warming influence, and only a small and insignificant cooling effect.

The explanation of the warming influence of an iceberg can be understood from the following. Consider an iceberg which is always composed of fresh water ice floating in the salt water of the sea. It produces by its melting fresh water, which is carried downward by the convective action of the inflowing salt water. (Current 2, fig. 1.) The surface water has no tendency to sink on account of its horizontal motion. In consequence of this all the heat radiated from the sun and sky, which is absorbed in this water, accumulates, and is not dispersed by the sea water movements. The wind stirs up the waves, but this action does not extend very deep. It is only by the convestive circulation that the sun's heat is distributed to a greater depth. In this way the water around the berg becomes warmer than the surrounding sea temperature, and produces the rise of temperature always observed first on approaching an iceberg.

The popular belief is that ice cools the water, but the cooling action of an iceberg is enormously less than the accumulative heating action of radiation on the surface of the sea. It is true that the presence of colder currents are told by the fall of temperature, but this does not mean that an iceberg is in the immediate neighbourhood. It merely means that ice may be expected. The actual effect of an iceberg is to produce a rising temperature in its immediate vicinity.

Icebergs may be approached without showing any cooling effect at all but only a rise: on the other hand, a cooling effect may be observed after the rise, but this is not due to the direct action of the ice, but to the fact that the iceberg is being carried along by a more rapid current, and therefore a cooler current. The cooler current would have been met with had no ice been about. Only one thing is inseparably connected with the action of the ice, and that is the rise of temperature.

Contradictory as these conclusions may seem, they are accounted for on sufficient grounds quite apart from the facts revealed through the charts and diagrams now to be described.

Description of the Microthermograms taken during the Trip of the C.G.S. 'Montcalm.'

In the following series of diagrams I show the reproduction of the actual temperature charts as obtained on the microthermometer. The time scale is shown in one hour intervals in most cases: the speed of the ship was usually 11.5 knots per hour. The temperature scale most used is the one which reads one degree centigrade for two divisions of the scale. The finer scale was used for the more detailed study. Any further reduction of the scale is not to be desired, inasmuch as this is the coarsest scale that can be used to advantage in determining the small variations in sea temperature.

A special detailed study was made of the iceberg shown in figs. 7 and 8. These photographs are taken from different points of view. The berg was floating slowly southward at the rate of about two miles per day. When studied it was about ten miles off the eastern end of the strait of Belle Isle, and well removed from the land and other icebergs. The morning was hazy with a bank of light fog hanging further to eastward. The wind was light and from the north-east, and the sea was fairly calm.

Courses were arranged for the ship from different points of the compass, from radii about six miles in length. Thus a continuous trace of the temperature was taken over a north and south course, and an east and west course, and intermediate courses.

Fig. 9 shows a sample of the temperature traced from the microthermogram record in this study. The horizontal scale is in hours or ten mile intervals. The vertical scale is in tenth degree intervals on the microthermometer scale. The curves were automatic, and, as shown here, start from a point three miles from the berg, the course being directly towards the berg. It will be seen that the temperature rises steadily until the ship passed abeam a few yards from the ice, when the temperature fell again regularly up to the end of the six mile radius. Coming back a similar curve was traced, but the berg was passed on the other side. In this case the temperature rose steadily until abeam of the berg when it took a small dip and then continued to rise for a mile on the other side. Returning, and passing the berg at the same side as at first but nearer, a higher temperature was recorded followed by a small dip as before, then a rapidly falling temperature as the berg was left astern. The cooling effect of the melting ice was shown by the small dip of temperature of about a tenth of a degree on the course of the curve. The third curve, peaked, is for one of the other icebergs studied. Here just abeam of the berg, the ship circled right around it. A small cooling effect was noticed on the thermometer the same spot being passed over twice by the ship. On sailing away from the berg the temperature continued to rise for a short distance before it fell again as the berg was left behind.

In order to show more clearly the distribution of temperature about an iceberg I have prepared diagram 10 from the temperature curves and the notes from the ship's log. This diagram gives the isothermal lines as they were distributed about the first berg on the day we made the records. On the diagram I have shown the five mile limit, the direction of drift of the berg, and the approximate direction of the wind.

The highest temperature is in a small spot just a mile to the north of the berg. Another zone of high temperature existed a little to the west of the berg. What determines these zones of high temperature has not as yet been determined, but there can be no doubt at all of the influence of the iceberg in causing this rise of temperature in its immediate neighbourhood.

Fig. 11 shows a trace of temperature taken through the strait of Belle Isle from a point abeam of Belle Isle to point Amour at the western end of the strait. The effect of ice melting on the temperature of the sea water is very distinctly seen in the diagram.

The first group of icebergs was passed very close, some excellent photographs being taken. There were about seven of them apparently moving together at a distance ranging from a quarter to half a mile.

Leaving this group behind, the ship steered a straight course down the strait. The temperature fell as soon as the ice was left behind. One berg situated a mile off produced a small effect on the thermometer as the ship passed through its zone of influence. When the ship passed a string of growlers and small pieces, a smaller rise of temperature resulted. A second and a third group of bergs were passed before entering Forteau bay, and coming to anchor at point Amour, but their positions are clearly indicated on the chart.

It is interesting to see how the iceberg effect is superimposed on a changing sea temperature. Thus in fig. 12 I show the trace of temperatures taken from point Rich, Newfoundland, to point Amour. In this curve a rapidly falling temperature results from the passage from the warmer waters of the gulf of St. Lawrence into the colder arctic current sweeping in through the strait. I have indicated in the charts the points where icebergs affected the records. The berg at a quarter of a mile shows clearly a small cooling effect.

Fig. 7. Iceberg which was used to obtain the isothermal lines shown in Fig. 10.

Fig. 8. Nearer view from another position of the iceberg used for the purpose of studying the isothermal lines shown in Fig. 10.

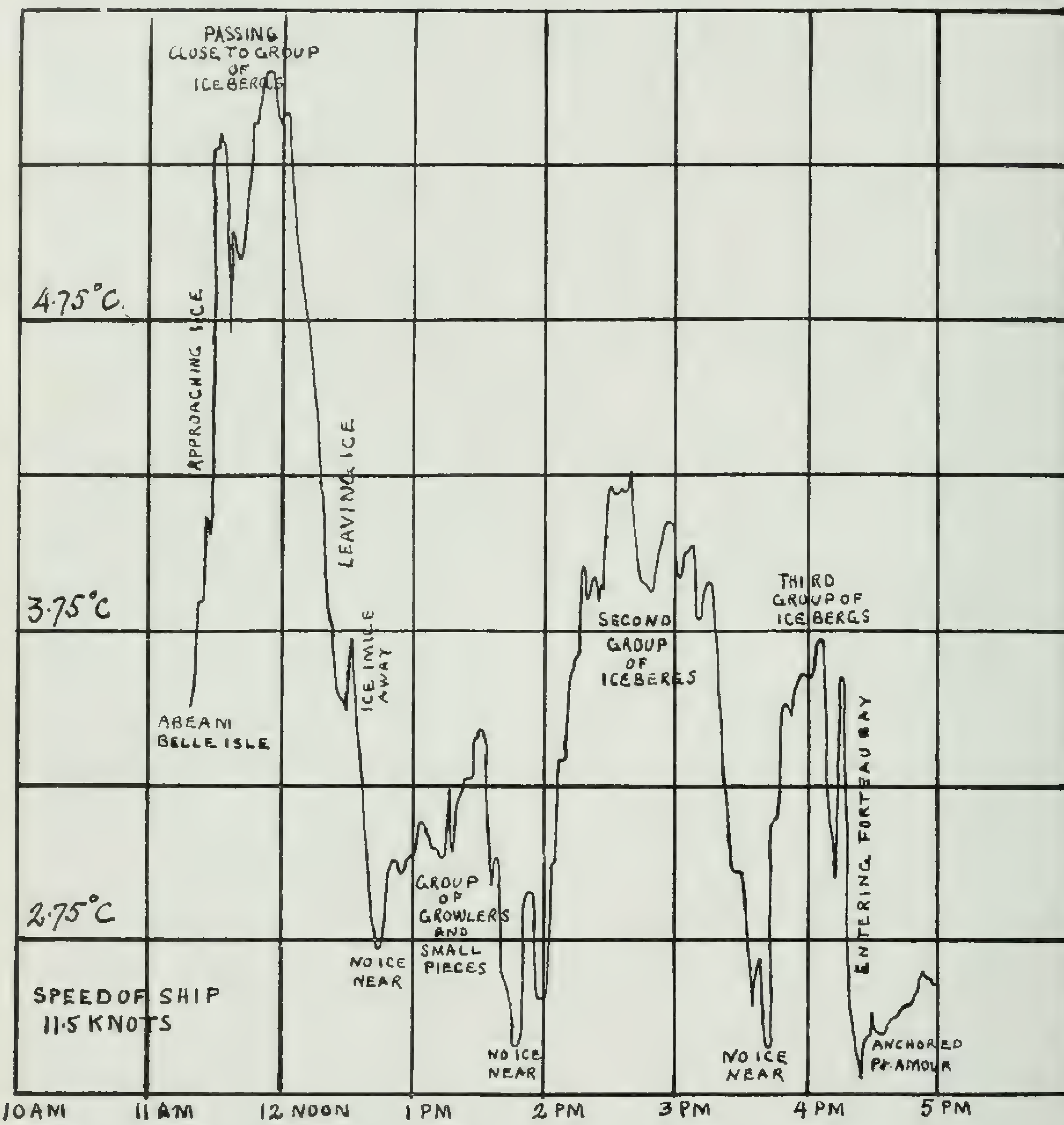


Fig. 11. Temperature trace through the strait of Belle Isle showing warming action of Icebergs.

Effect of Land and Shoals on the Temperature of the Sea.

In the records obtained for me by Mr. King on the trip to Hudson bay it was shown how very well the effect of land on the temperature of the sea could be told. Whenever the *Stanley* steamed towards the shore for the night the temperature fell rapidly. During my investigations of icebergs on the *Montcalm* I made a special effort to determine what effect the land would have through the strait of Belle Isle. This is a most important matter and one deserving of the most careful investigation. The effect of the coast of Labrador in cooling the arctic current was very marked. Anywhere within approximately six miles of the coast line the temperature fell below the surface temperature and continued to drop right up to the coast itself.

The explanation of this lies in the actions of the tides, and the obstruction offered by the coast line, resulting in the turning up of the under water which is always much colder than the sea surface. Hence where the disturbance exists, we may expect to have the water colder and full of streaks of warm and cold water. Far away from shore the temperature of the open sea is quite uniform, and specially in the arctic current. Near to land the temperature shows greater variations, which indicate the distributing influence of the shoals and land. My records of temperature across the ocean made on the Royal George show the wonderful uniformity of the temperature of the Gulf stream except near the coast of Ireland.

There are three things which affect the uniform temperature of the sea, and these are icebergs, land, and current boundaries. Of these it is possible to tell the presence of ice by the rise of temperature above the surrounding sea temperature. The effect of land is to send the temperature down. The great current boundary between the arctic current and the Gulf stream is well defined along the Canadian route and offers a position which might be made use of in navigation. Along the more northerly route the arctic current meets the upward moving Gulf stream and intermingles with it and is deflected eastward. To the south we have a shifting Gulf stream and numberless rises and falls of temperature, making it more difficult to detect the presence of ice, but on the northern route we have well defined boundaries which are narrow and restricted. By the Belle Isle route we have less than 250 miles of ice track, but on the New York lanes the track extends for 600 miles or more.

The effect of shoals in disturbing the surface temperature of the sea was first pointed out by Dr. W. Bell Dawson in a report presented to your Department on the influence of currents in the bay of Fundy. This very important observation has been completely confirmed during the progress of the present investigation. As an example of the many records I have of this, I select the trace shown in fig. 13. Here the course of the ship was directed from Heath point northward towards the strait of Belle Isle. The first part of the record is through very deep water far from land and ice, and shows the very small variations of temperature characteristic of such waters. The passage of the ship over a shoal of 25 fathoms is clearly shown by a dip in the sea temperature. The minimum reading on the thermometer corresponds with the position of the ship over the bank, and the passage again to deep water by the rise again, the ship's position being determined by the cast of the lead. The action must be due to the obstruction offered by the shoal in the under currents of colder water.

In fig. 14 I have shown the effect of the Anticosti coast on the temperature of the river at that point. The ship had been anchored for some time at the South-west point lighthouse and the instruments were set to record as the ship left the shore for the deep water of the channel. The temperature which was taken by the surface thermometer is seen to rise rapidly as the ship left the coast line.

During this course, which was followed to Heath point lighthouse, the ship drew in towards the shore until the effect of the land was again clearly marked. In fig. 15 I show the temperature trace in a line parallel to the coast, but so near as to be influenced by the streaks of colder water turned up by the land. The trace will be seen to be unsteady and quite unlike the uniform trace shown for the deep water in fig. 16. In fig. 16 I show the effect of cape Bauld, Newfoundland, on the temperature of the sea. The first trace represents the temperature across the eastern mouth of the strait from West point, Belle Isle, to cape Bauld. Here the temperature rises, first due to the influence of Belle Isle, then falls as a colder current is entered. A group of icebergs was passed which had more influence in causing a rapid rise of temperature, but when approaching the cape the temperature fell with great rapidity to a point much lower than any observed away from land. One iceberg grounded near the cape produced its effect just before coming to another abeam of the lighthouse.

The second trace in fig. 16 shows the effect of leaving cape Bauld for the open sea. The two curves are almost exactly complementary to each other and clearly indicate the effect of the coast line. The temperature trace is from the deep thermometer.

It is interesting to compare fig. 16 with fig. 17 which represents the trace of temperature taken on my return trip on the R.M.S. Allan Line *Victorian* early in June. Here the effect of cape Race to the south of Newfoundland is shown. When the ship was abeam of the cape at four miles distance the temperature fell so low as to be off the scale of the instrument. Unfortunately I was away from the instruments at the time, otherwise I would have been able to determine how low the temperature went. I found that the pen had come back on to the scale when I returned to inspect the chart.

The effect of cape Race is clearly defined here, and is similar to the effect of cape Bauld, to the Labrador coasts and to the coasts of Ireland and England.

Just before coming into the zone of influence of the cape, a small iceberg was passed, and this will be seen to produce the characteristic iceberg effect. There is no reason to doubt that the great cooling here is due to the deflection upwards of the cold arctic under water by the coast line of Newfoundland. Our nearest point to land which was 4 miles abeam of cape Race corresponded to the lowest temperature recorded. At no other point through the arctic current or gulf of St. Lawrence was so low a temperature indicated.

In fig. 18 I show the influence of cape Norman. This diagram represents a trace across the strait from Greenly island to the opposite shore. Iceberg records are shown in the trace. Fig. 19 contains two traces, the first one represents the course along the coast from cape Bauld to Kerpon harbour. Here the characteristic fluctuations near land are shown, together with the fall on coming to anchor in the harbour. The second trace represents that through the gulf along the Newfoundland coast, and the effect of approaching cape Ray. We anchored abeam of the lighthouse, the temperature near shore showing a minimum reading.

Fig. 20 represents the fall of temperature approaching land. The *Montcalm* had been anchored for some time off the coast abeam of Rich point. The course into Port Saunders for the night is clearly shown by the fall of temperature.

The general effect of land of lowering the temperature of the sea is clearly proved from these records. It is of the greatest importance to us to observe that the large effects produced by the coasts of Labrador and Newfoundland are so characteristic that ample use could be made of them to warn ships in time of fog of the proximity of the coast. Within a parallel to this coast of six miles the temperature drops so rapidly that the effect could not be mistaken by a navigator, while the entrance through the eastern mouth of the strait shows no such drop. Hence a ship making the strait in a fog could be sure of avoiding the rocks of the coast as long as the temperature was not dropping rapidly. I do not think it would be possible for a ship to get out of her course through the strait so as to hit the shore without ample warning on the chart of the microthermometer. For the same reason no ship could hit the coast by the Cape Race route in time of fog. If practical data uch as I have just presented counts for anything, then we are at last provided with a sure and safe

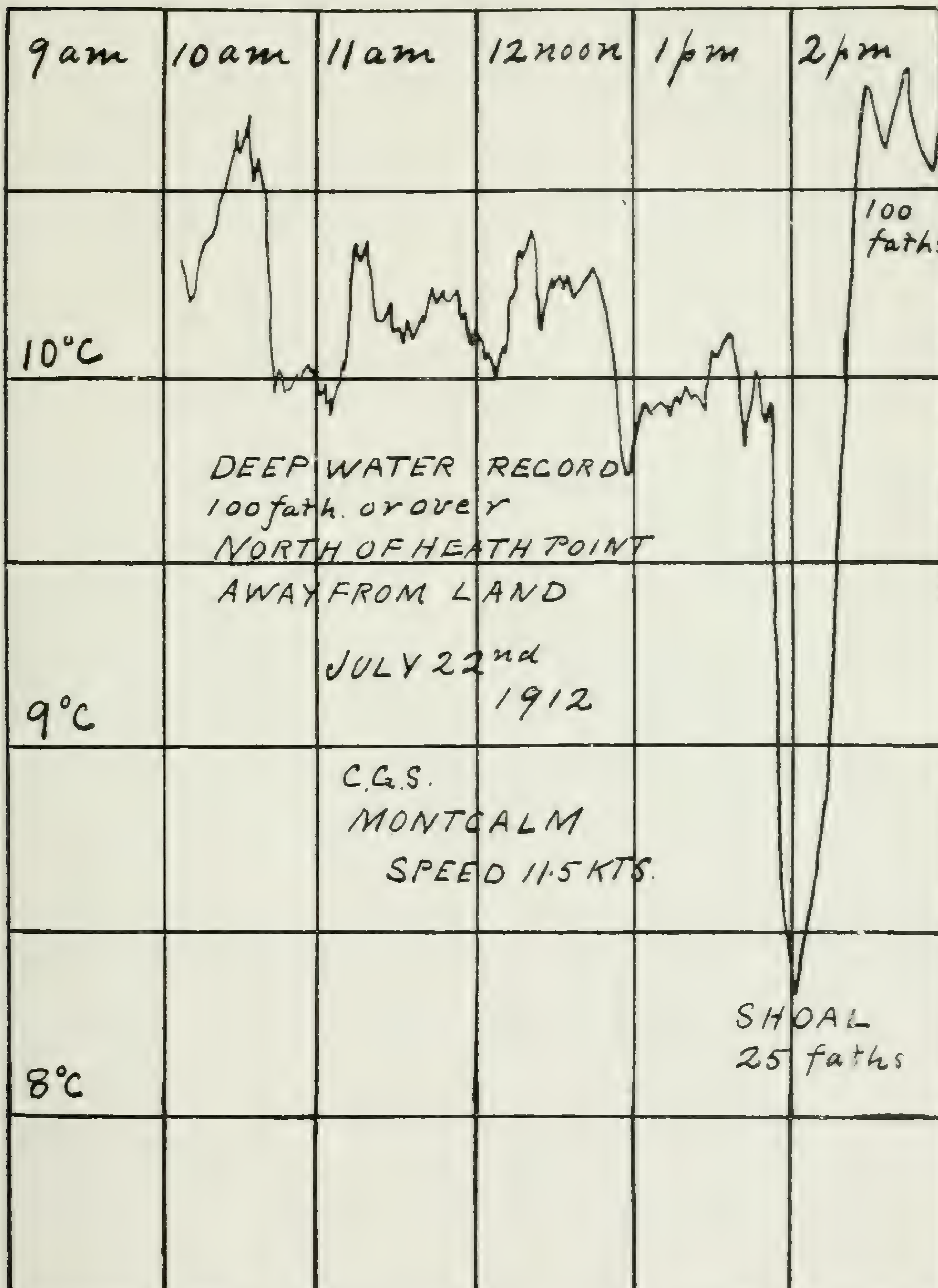


Fig. 13. Effect of a shoal on the temperature of the gulf.

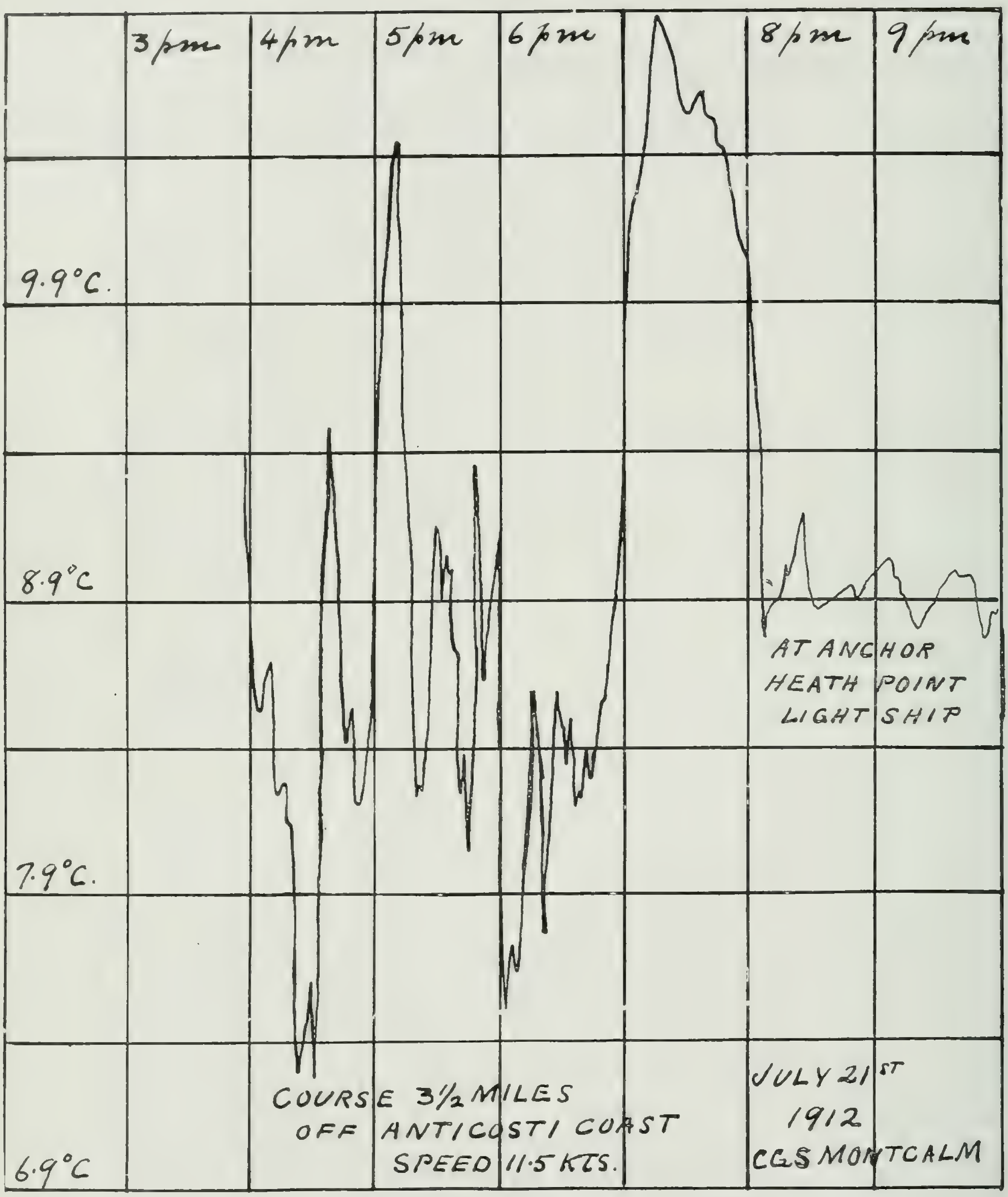


Fig. 15. Near land the temperature is very unsteady.

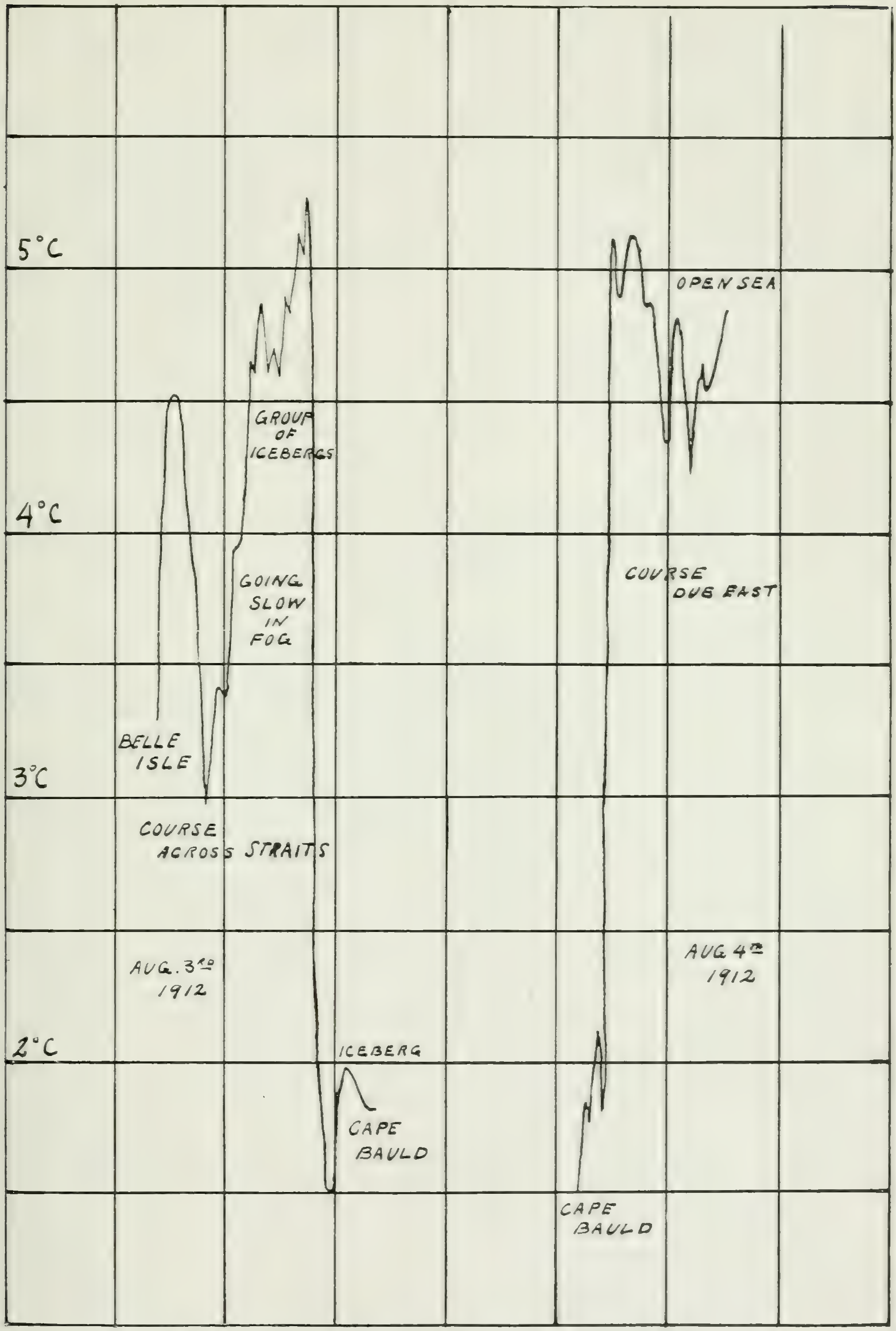


Fig. 16. Effect of cape Bauld on the temperature of the sea.

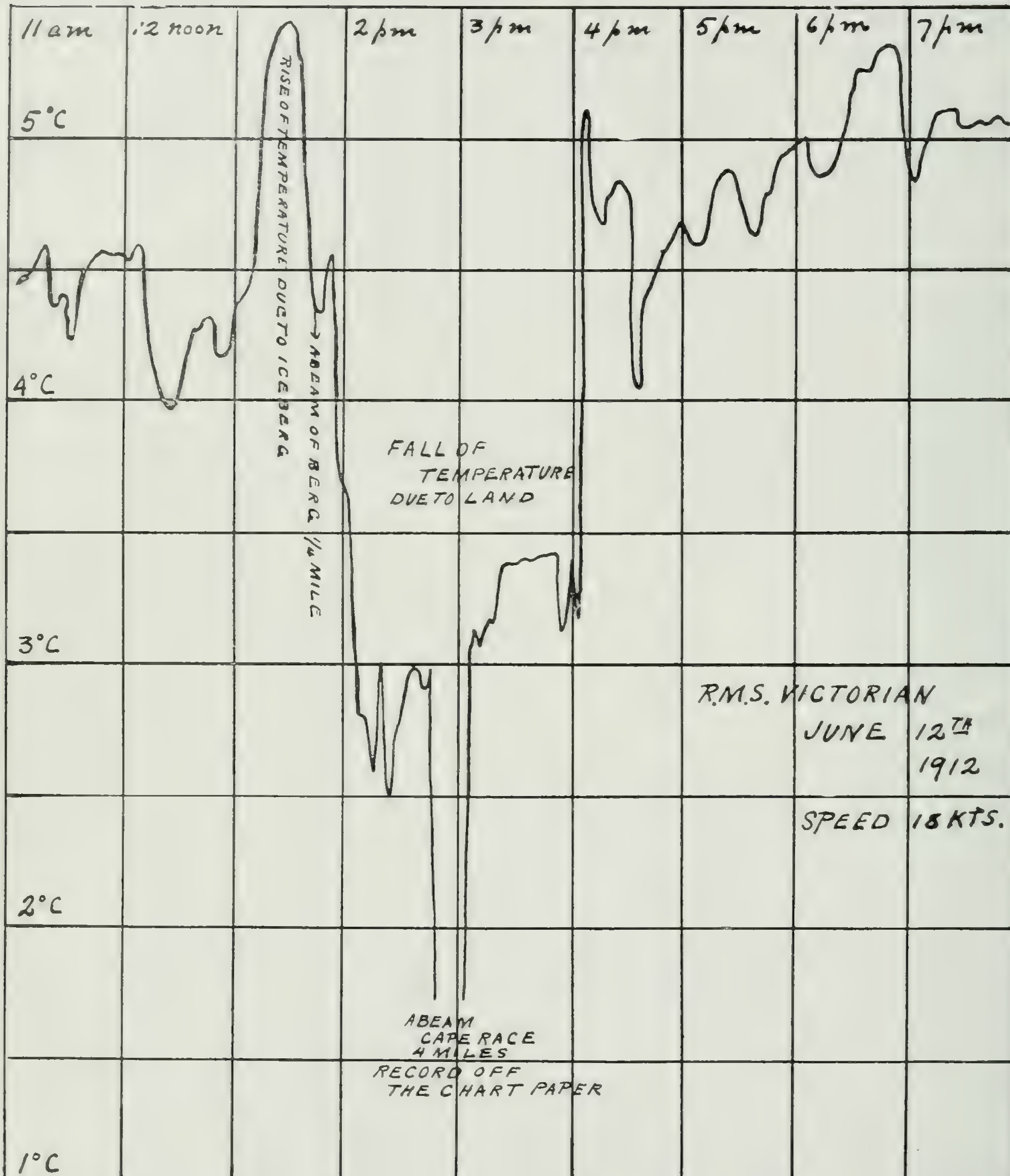


Fig. 17. Effect of cape Race on the temperature of the sea.

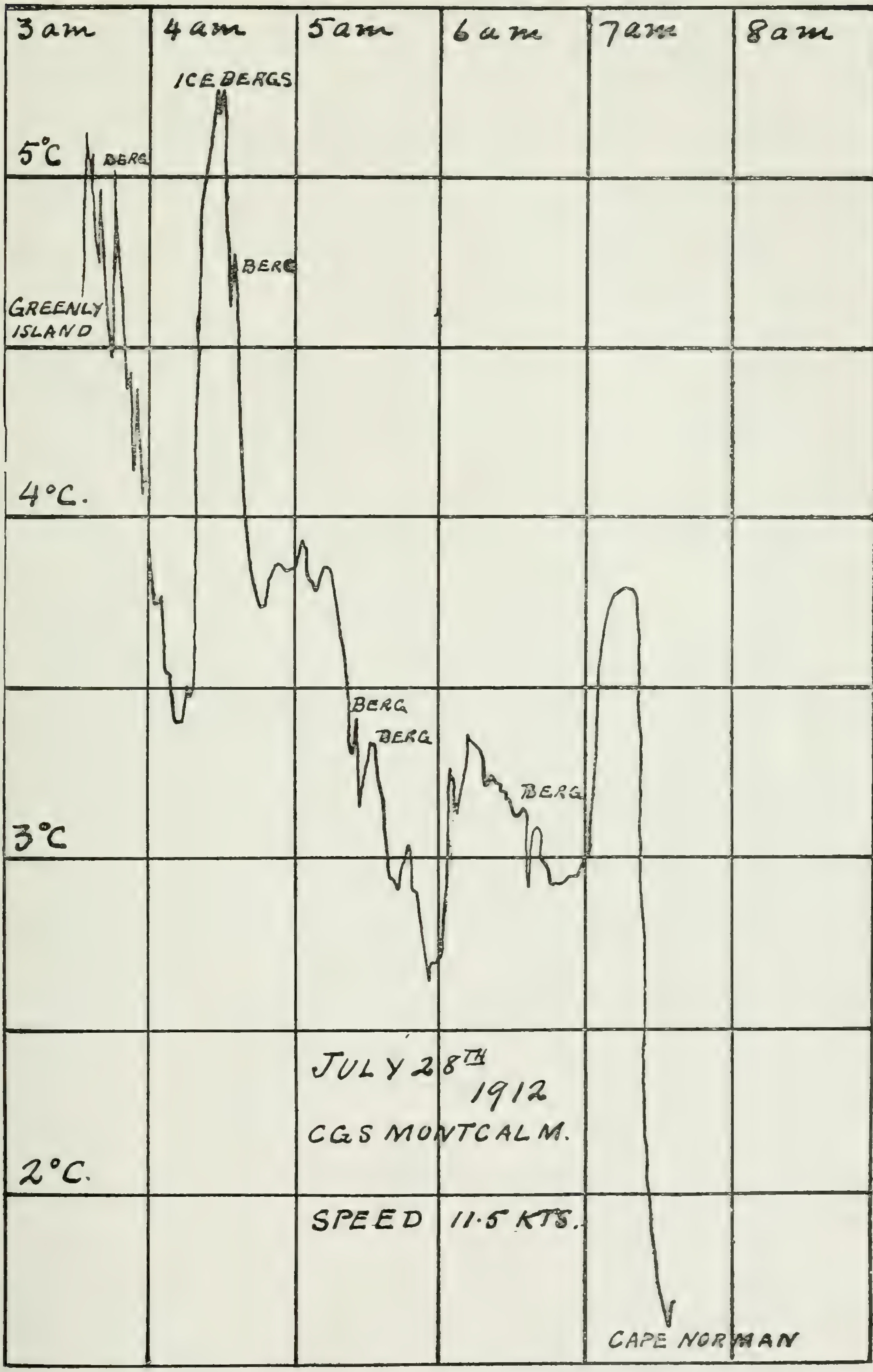


Fig. 18. Temperature trace across the strait of Belle Isle.

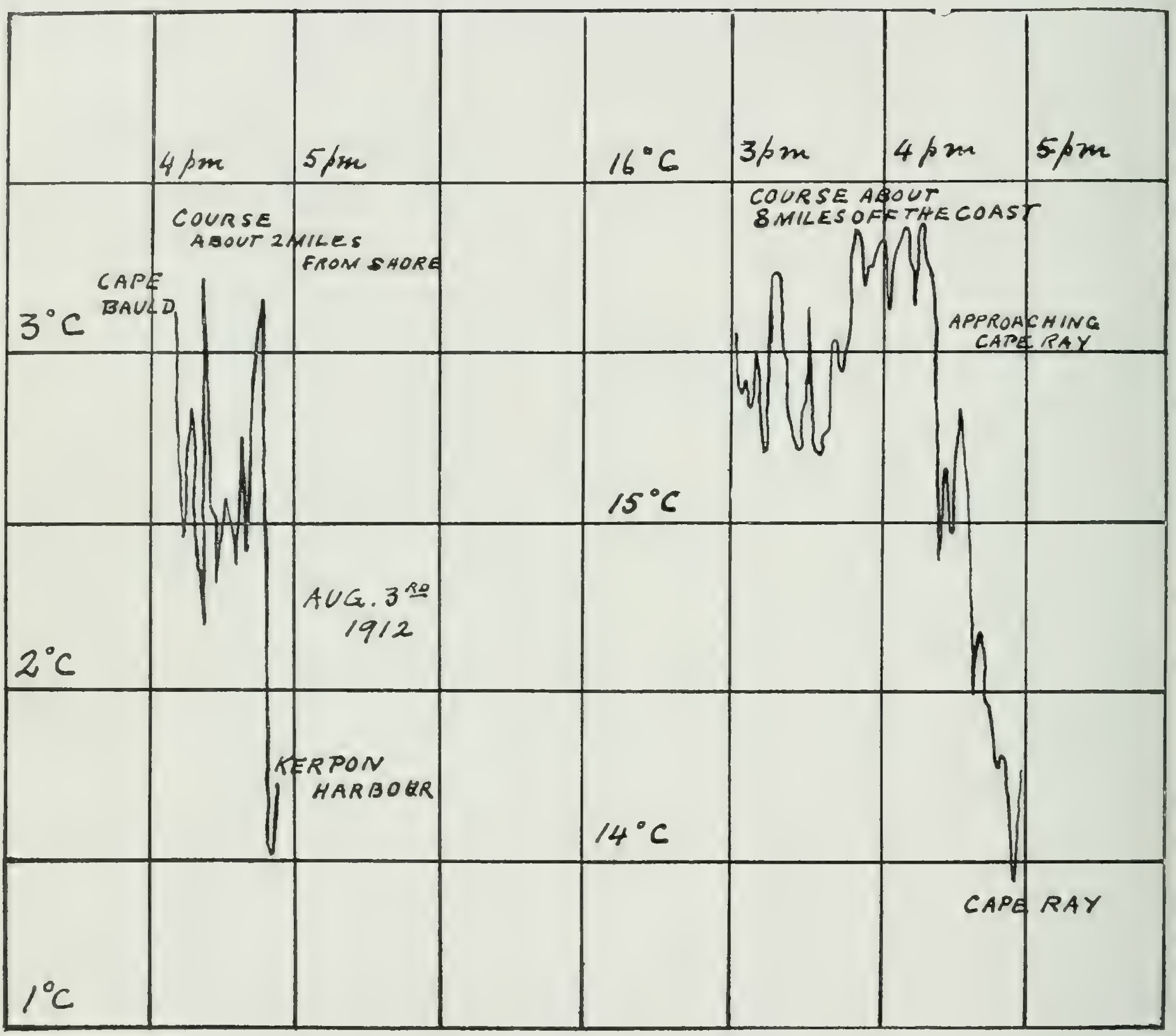


Fig. 19. Temperature trace showing the effect of land.

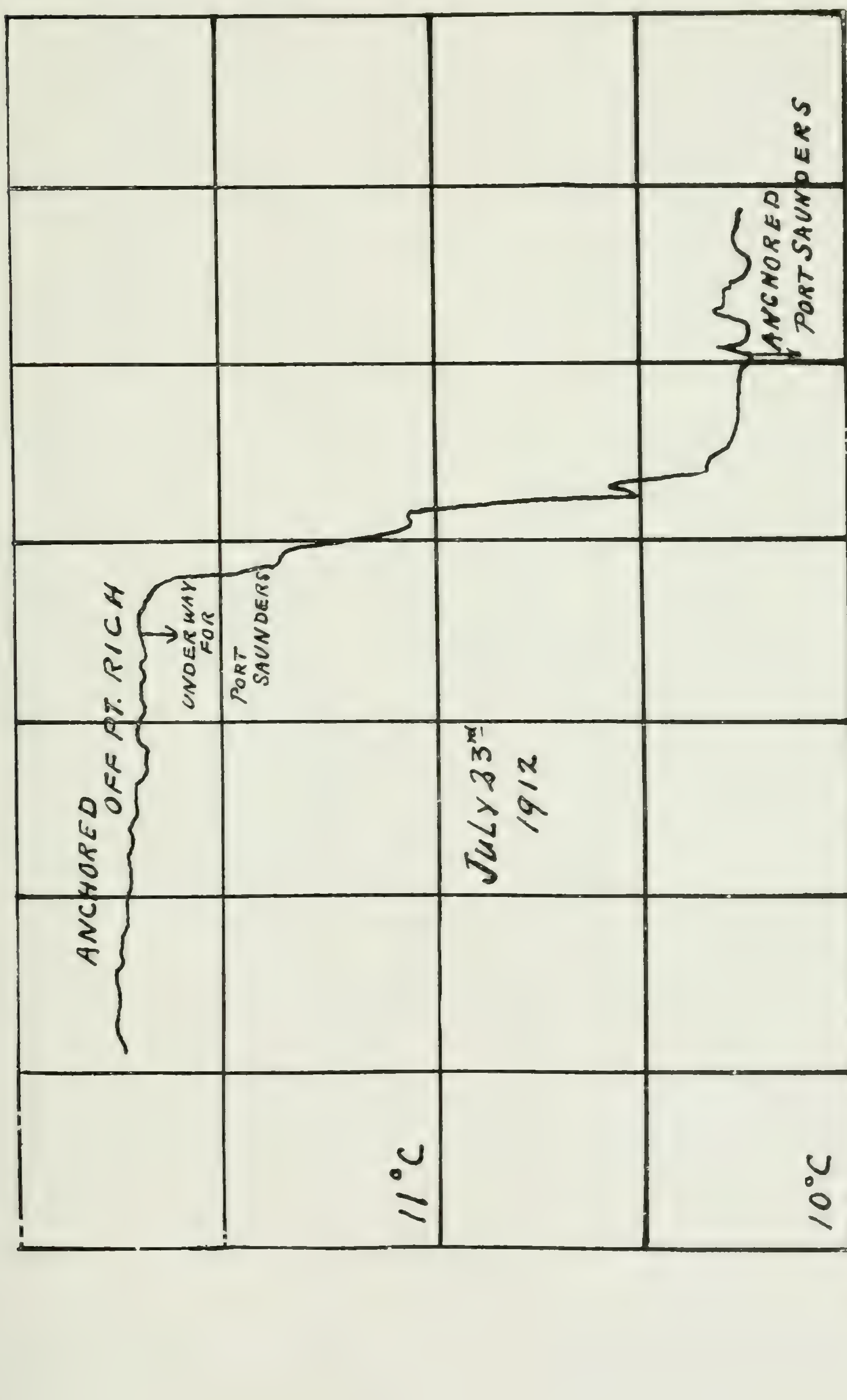


Fig. 20. Temperature trace showing the effect of land.

method of avoiding the chances of shipwreck that have hitherto confronted navigators of the St. Lawrence route.

Current Boundaries.

As I have already pointed out, the boundary of the arctic current and the Gulf stream is very well defined along the Canadian route, so much so that it is likely that the determination of this on any particular route would enable a ship to define its position with some certainty. To show this, I give a trace of temperature which I obtained on the *Victorian* entering the ice-track off the cape Race route. In fig. 21 the sharp wall of separation between the two currents is clearly seen and well defined. The course through the ice track is one of gradually falling temperature as the coast of Newfoundland is approached. The small rises of temperature observed up to 8 p.m. are due to icebergs at various distances of 6 to 8 miles. The nearest approach to a berg was between 9 and 11 p.m. when the ship was running dead slow in a fog. An immense iceberg was passed at a distance of one mile, but the effect of this berg is clearly seen by the great rise of temperature produced. The cold current in which the berg was floating was passed between 10 and 11 p.m. All this time the ship made hardly five miles. Long before the big berg could be seen, the record of it was unfailingly shown on the chart, and ample warning was thus given by the micro-thermometer. The minimum reading is in direct line with the gradual drop in the temperature curve, and cannot be said to be in any way caused by the ice. The presence of the ice is shown by the large rise in temperature.

Fig. 22 is interesting as representing the temperature wall of separation between the arctic current and the Gulf stream, as obtained on the more southerly route from Halifax. This illustrates what occurs with greater frequency along the more southerly route. A streak of cold water has penetrated into the warm Gulf waters, and causes a rapid fall of temperature after the first boundary has been passed. Streaks of arctic water, as shown here, may be ice-bearing and cause a great menace to navigation.

The Salinity of the Sea in the Neighbourhood of Ice.

In order to test the influence of icebergs melting on the dilution of sea water, I determined to collect and bottle numerous samples of sea water and test them by the electrical conductivity on returning to the laboratory.

The question of salinity is one that presented itself to me when I first became familiar with the important tank experiments of Prof. Pettersson. I was desirous to determine if possible the effect of the surface water of the berg in diluting the sea water. A number of 4 oz. bottles were provided, and at intervals a bucket was thrown over the side and samples of water drawn up. The bottles were filled from this, then carefully labelled, corked, and put away.

On my return to the University the measurement of conductivity was kindly undertaken by Dr. McIntosh and Mr. O. Maass of the McGill University Physico-Chemical Department. The tests were carefully made, all the samples being kept at a uniform and equal temperature of 26° C. The following table gives the results of the test.

TABLE OF SALINITY.

No. Samples.	Locality.	Resistance.	Conductivity.
1	In the river abeam of Metis	2075	·04556
2	Off Anticosti island	1943	·04866
3	West end Belle Isle strait—Depth 125 fathoms	1919	·04928
4	Port Saunders harbour	1950	·04850
5	In the rise of temperature from iceberg	1943	·04866
6	Point Amour light-house—Much rain during the night	1919	·04928
7	In the rise of temperature caused by an iceberg	1919	·04928
8	Crossing the strait	1983	·04768
9	Duplicate of same	1983	·04768
10	Close to berg near shore at cape Bauld.	1888	·05007
11	In the strait, eastern end	1959	·04827
12 & 13	Duplicates	1967	·04806
14	In the open sea long way from icebergs	1950	·04850
15	Close abeam large berg	1975	·04787
16	One mile north same berg	1967	·04806
17	Close abeam to same berg	1959	·04827
18	Six miles away from same berg	1983	·04768
19	70 yds. to leeward of big berg	1975	·04787
20	40 yds. to windward of same berg	1975	·04787
21	120 yds. to windward of another berg	1975	·04787
22	100 yds. to leeward of another berg	1967	·04806
23	50 yds. to windward of another big berg	1975	·04787

An inspection of these numbers shows at once that the dilution by the berg is very small and cannot well be distinguished from the small changes in salinity observed in various parts of the sea. If we take observations 14, 15, 16, which were all made over the course followed in preparing the temperature charts, it will be seen that a very small effect is indicated, but observations 17 and 18 from the same berg cannot be said to agree. Abeam of the berg we have a slightly smaller conductivity as contrasted with the condustivity in the open sea a long way from it. I believe that the changes in salinity observed may indicate a small dilution by the iceberg, but that this dilution cannot be distinguished from the variations in salinity normally met with in the Atlantic waters.

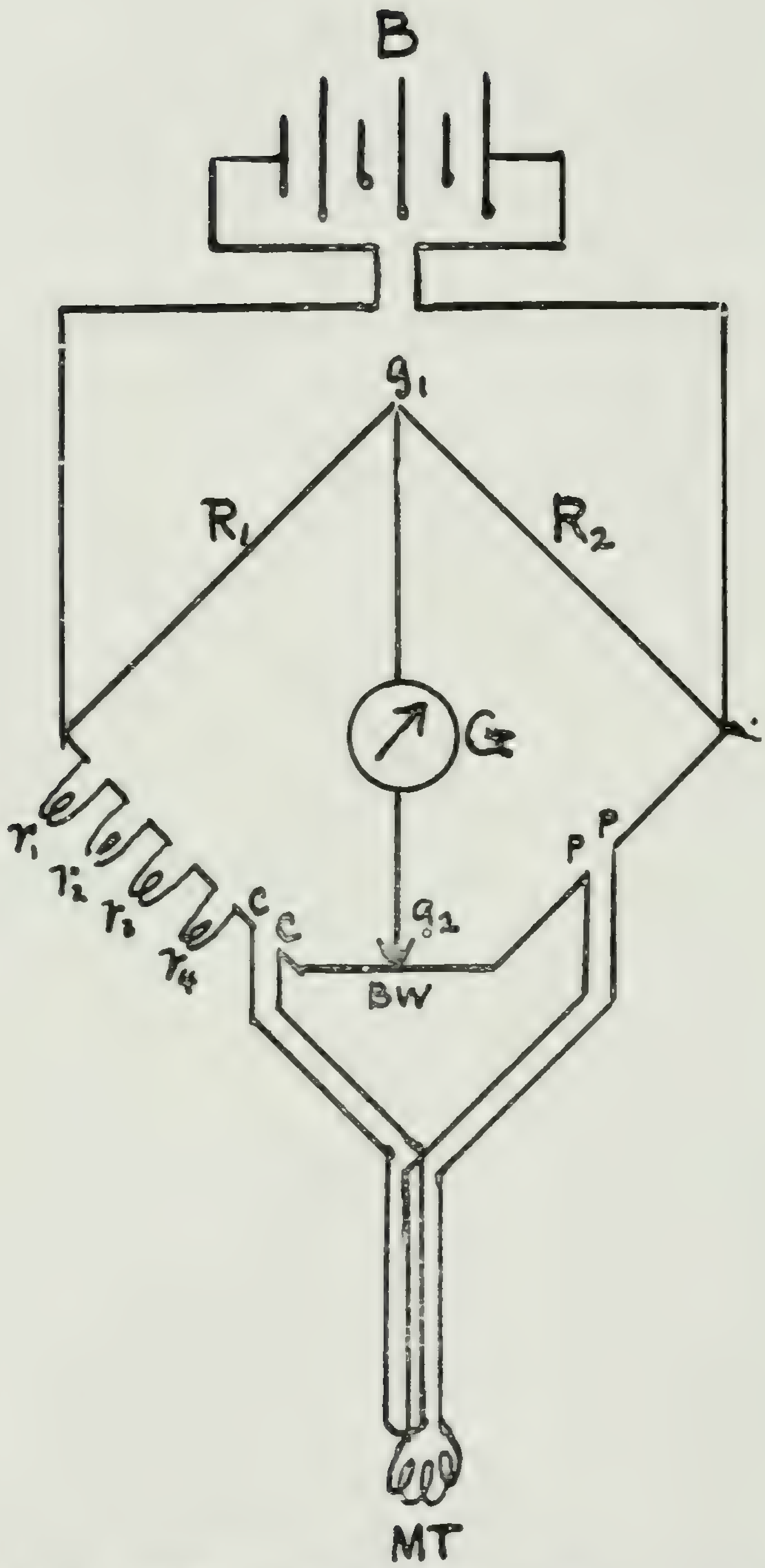
Observations 19 and 20 are interesting as representing samples taken to leeward and windward of a large iceberg. We must conclude therefore from these tests that measurements of salinity cannot be used for telling the proximity of ice, and that if a small dilution exists, the effect caused by the thermal absorption in the surface currents of the water drawn towards the berg is of more importance.

It is interesting to compare the values here given with the measurements I obtained from water brought from Hudson bay. These tests give for the electrical conductivity the value .0480 at 26° C., which is the same as the values found in the strait.

Sample No. 1 shows the effect of the dilution caused by the fresh waters of the St. Lawrence mingling with the sea water. Where so small an effect as this is produced by so great a volume of fresh water moving seawards, it is little wonder that an iceberg has so small an influence on sea salinity.

Sound Echoes from Icebergs.

The question of the echo of the steam whistle or fog horn as a means of telling the presence of icebergs is an interesting one. I had very good chances to observe this. While at anchor abeam of cape Bauld the fog horn from the lighthouse was repeatedly echoed from bergs in the immediate neighbourhood. As many as three



g. 23. Diagram of Wheatstone's bridge connection as used in the microthermometer.

echoes following one another could be heard. The best one was from a berg grounded a quarter of a mile from the ship. It was observed that the change of position of the berg made a great difference in the intensity of the sound returned. In addition to the iceberg echo there was a distinct echo from the fog bank lying off the shore.

I am sure that the presence of an iceberg can be told in some cases by the echo received from the steam fog horn. This warning is not certain however, as we have abundant evidence to the fact that fog horns are not always heard in a fog, even at close range.

Conclusions.

In conclusion I must report as a result of my study of icebergs and land that very important results have been obtained, indicative of methods which should be developed for equipping ships for avoiding ice and land. The experiments have been so decisive and reliable that I must strongly recommend that attention be devoted by the Government and by steamship companies towards adopting accurate temperature recorders on board ship.

The fact that ice sends the temperature up and land sends it down will serve to distinguish clearly these two effects. Again I must emphasize that it is to a study of the variations of temperature in the sea, and not the temperature itself, which will enable navigators to safely avoid ice and land at night or in time of fog.

I would strongly recommend the Government to equip at once a ship to map out the isothermal lines around the coasts of Newfoundland, Labrador, and the shores of the gulf of St. Lawrence and strait of Belle Isle, for in so doing a chart could be prepared which would be of great assistance to navigators using these waters.

Similar charts should be made all over the world, but this is a matter for international action and not for one Government alone. By acting at once, our Government will be serving a most useful purpose and starting a work of the greatest importance to humanity.

APPENDIX I.

The Microthermometer.

The general principle of the microthermometer is that of the Wheatstone's bridge. (Fig. 23.) Two ratio coils R_1 and R_2 of equal resistance form two arms of the bridge. A third arm includes the bulb MT connected by the wires PP to the bridges. A fourth arm consists of connecting wires CC from the bridge to the bulb, but containing no resistance coil. The wires CC constitute Callendar's compensating system, and serve merely to annul the changes of resistance in the wires PP as they might affect the bridge system. A galvanometer G_2 is connected across the bridge, dividing it into two equal portions. The battery B serves to send an electric current through the bridge. This current divides on entering the bridge and takes the circuits R_1, R_2 and CC PP. A resistance wire forming what is called a bridge wire Bw connects the two arms CC and PP. A series of resistance coils V_1, V_2, V_3, &c., are connected in the fourth arm of the bridge. One of the galvanometer contacts is made to slide over the resistance wire Bw. When normally connected the resistances V_1, V_2, V_3, &c., are made equal to the resistance of the bulb MT. The ratio coils R_1 and R_2 being equal, the electric current divides between the two paths. When the resistances of V_1, V_2, &c., equal the resistance of the bulb MT no electric current can pass across the galvanometer circuit in either direction, R_1 and R_2 being equal and fixed. When the temperature of MT changes its resistance changes, and in consequence the balance of the bridge is changed and a current passes through the galvanometer G_2. The direction of the current will depend on whether MT increases or decreases from its zero position.

Small changes of resistance in MT can be compensated for by sliding the contact G_2 over the resistance wire BW, and so the zero position of the galvanometer can be readily restored. The movement of the slide G_2 over the wire BW gives a measure of the change in resistance of MT, and therefore the change in temperature of the bulb. Large changes of resistance in MT can be compensated by changing the coils V_1, V_2, &c.

The adaptation of this principle to the microthermometer consisted in. (1), Making the bulb MT large, strong, and of high resistance, so that small changes in temperature would produce large changes of resistance. (2) Making a suitable galvanometer which would be sensitive and free from vibration. (3) Selecting a suitable recorder by which the contact G_2 could be moved automatically and record itself on a sheet of paper.

The Bulb.—In the construction of the bulb it was necessary to combine great strength with maximum sensitiveness. This was made easy from the fact that size was of no account. I finally adopted the concentric ring type of bulb which I had devised and described many years go. Figure 24 shows the general cross section of the bulb. A central copper tube with flanged edges 4 inches in diameter and 6 inches long serves to hold the resistance wire. An outer copper tube fits over this concentrically and the edges are carefully soldered water-tight. A heavy side tube is fastened firmly on through which the wires pass to the armoured cable carrying the wires to the recorder. Heavy copper pipe protects the armoured cable from the action of the sea water. The resistance wire was selected with great care. Iron wire was chosen for two reasons: on account of its high temperature coefficient, and from the remarkable steadiness of its resistance at the temperature of the ice point. Much experience with platinum had shown it to be liable to small changes of zero, which fact had not been noticed with iron. The cheapness of the material enabled me to use a wire of large size, and to avoid by this means the heating of the bulb by the passage of the current from the battery.

In all 250 feet of silk covered wire ·013 inch in diameter was wound on, and the ends soldered to copper cable at the junction of the side tube. The resistance of this coil was approximately 125 ohms at O° C:, and had a temperature change of a little over half an ohm per degree centigrade.

The space between the concentric copper tubes was made as small as possible to make the bulb respond as quickly as possible with a change of temperature. Special tests made in water showed that the bulb temperature followed the water temperature with a time constant of ten seconds, ensuring by this means that no serious error resulted when the instrument was used to follow rapidly changing sea temperatures.

The Galvanometer Relay.—This instrument was adapted from a sensitive Weston portable galvanometer. Revolving contact points as in Callendar's recording galcanometer were used but of new design. The index of the galvanometer needle supplied either right or left hand electrical impulses through the revolving contracts. A deflection to one side or the other engaged the contacts which set in motion a circuit attached to the magnets of the recorder. The resistance of the galvanometer was approximately 300 ohms. It worked exceedingly well, having so slow a period as to be independent of the vibrations on board ship.

The Recorder.—The records were made by a pen on a chart paper and gave by this means a continuous trace of water temperature. The instrument is the same as a Callendar temperature recorder. Figure 25 shows a diagram of the parts and connections of the recorder.

The impulses of the galvanometer G are imparted to the contact wheel W of the clock C, and sent to either one of the magnets m or m_1. Each magnet when

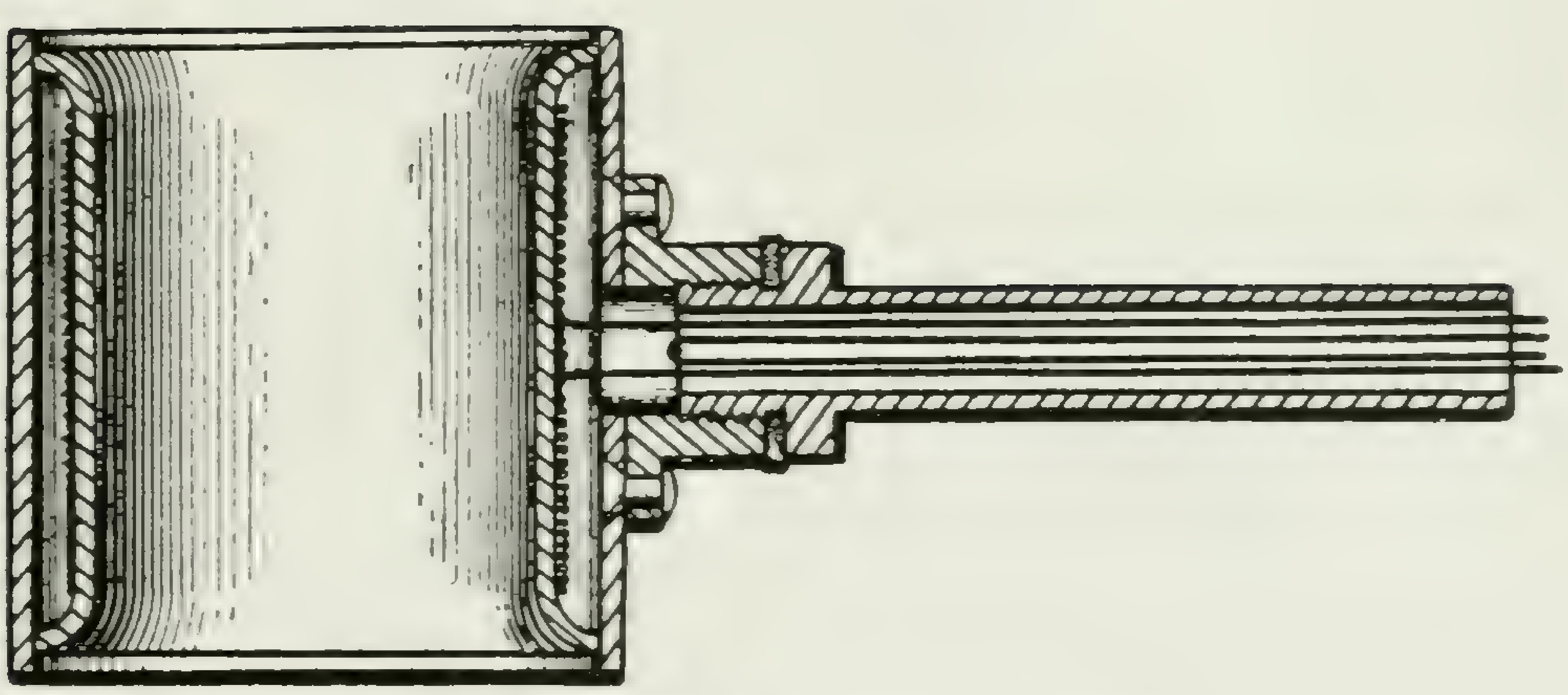


Fig. 24. Bulb of microthermometer.

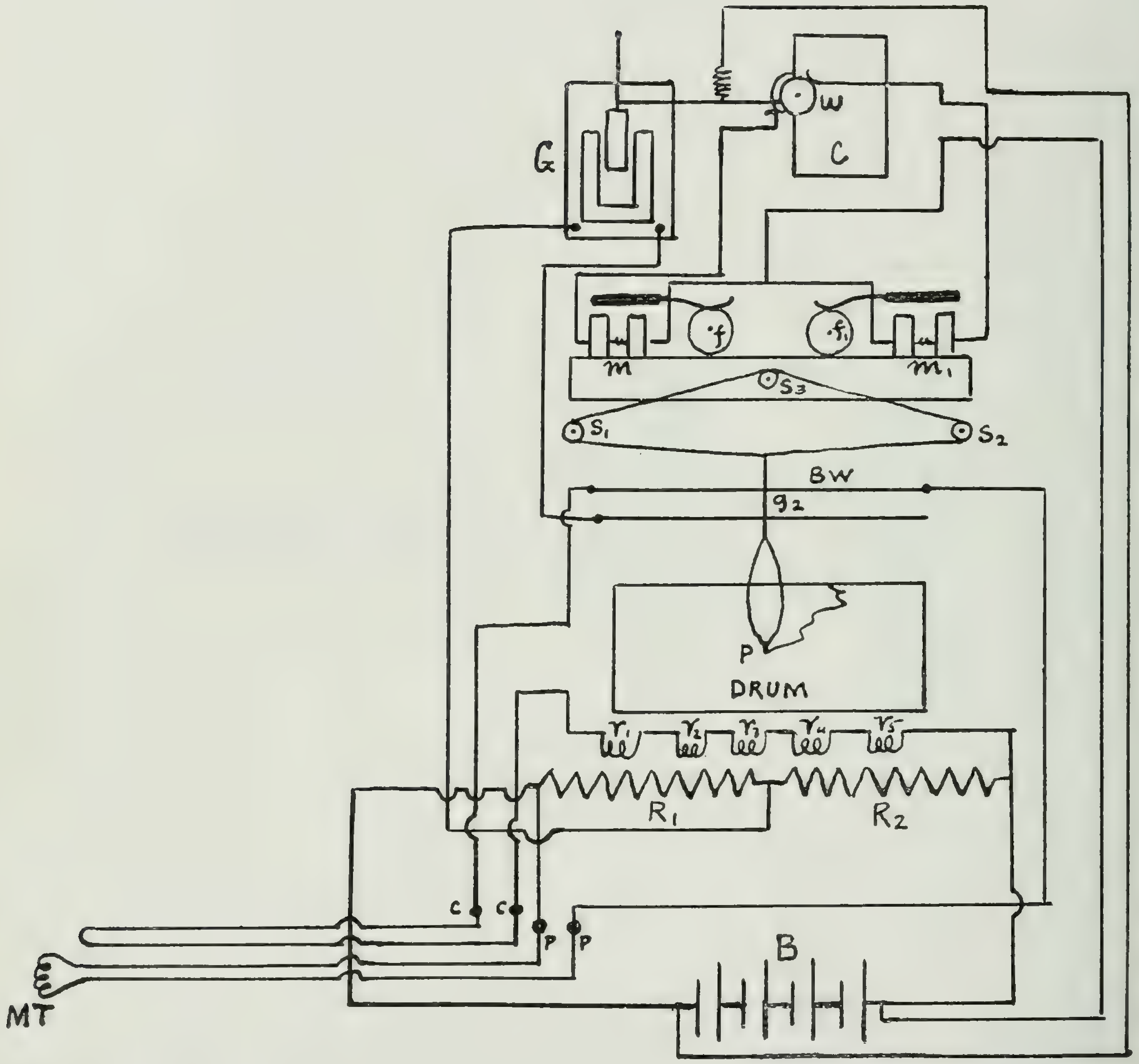


Fig. 25. Diagram of connections for the microthermometer with the Callendar recorder connections.

excited pulls down the armature and lifts the friction brake from either of the wheels f and f_1. This sets in motion a clock-work mechanism and differential gear which turns the spindle S_3. From S_3 a chord passes over S_1 and S_2 and holds the pen P on the drum. The rotation of S_3 either clockwise or counter clockwise moves the pen P to the right or to the left. The pen P is an extension of the contact G_2 (see fig. 23) on the resistance wire BW.

The operation of the recorder is as follows: A change in the resistance of the bulb deflects the galvanometer relay G to the right or left. In either case, one or the other of the magnets m and m_1 is excited, and the spindle S_3 rotated by the differential gear in such a way as to move the contact G_2 on the resistance wire BW. By this means the galvonameter contact is moved automatically to the position of no current through the galvonometer circuit, and thereby the bridge balance is restored. A change of temperature in the bulb causes by this means a change of position of the pen on the drum and gives a permanent record of temperature changes.

Battery Current.—The exciting current was supplied from a battery of five dry cells (Columbia 18 ampere hour capacity). The relay circuit was supplied by a battery of three dry cells. On account of the high resistance of the circuits these cells lasted over a long period for a continuous run.

Connections for the Instrument.

The bulb may be connected directly as shown, in which case the resistance is compensated by a known resistance box, V_1, V_2, V_3, &c., or the bulb may be connected differentially with a second bulb equal to it in resistance. (That is the second bulb takes the place of the resistance box).

In the first case the reading of the resistance box together with the bridgewire resistance gives a measure of the temperature. In the second case the difference in temperature only can be read. Such might prove useful in getting the difference in temperature between the bow and stern of a ship for navigating purposes.

APPENDIX II.

Salinity of the Arctic Current.

Since preparing this report, I have obtained measurements of the salinity of the sea through the Arctic current by the route through the strait of Belle Isle. This was made possible through the kind assistance of the Canadian Pacific Railway Atlantic Steamship Co. In October, 1912, the microthermometer was installed on the *Empress of Britain,* and microthermograms obtained on the eastward and westward passage through the strait. Samples of seawater were collected every hour through the ice track, commencing about 40 miles east of Belle Isle. On the return journey duplicate samples were taken off the mouth of the strait. These samples were carefully bottled and brought back to the laboratory when the salinity was determined by the electrical conductivity method. In every way the treatment was the same as for the samples already described in this report, except the conductivity was determined at a uniform temperature of 25° instead of 26° C. To compare the results a correction of 2 per cent must be added to the present series, since the conductivity at 25° is 2 per cent less than for the same sample at 26° C.

Table of Conductivity (Temp. 25° C). ....

In the strait..	·04806
Nearly abeam Belle Isle, East end..	·04865
40 miles east of Belle Isle..	·04986
70 miles " "	·05047
100 miles " "	·05214
200 miles " "	·05235
260 miles " "	·05257
462 miles " "	·05257

These results which are taken at random from the whole series show a gradual rise of salinity from Belle Isle through the Arctic current. The numbers all show a gradual rise and are remarkably consistent. This result is interesting in showing the effect of the Arctic current in diminishing the salinity near the mouth of the strait. My determination of the conductivity for the water of Hudson bay, which agrees so well with the water in the strait of Belle Isle shows how directly the waters from the north influence our easterly coast. Less than 200 miles east of Belle Isle we leave the influence of the Arctic waters, and pass rapidly into the waters of the Gulf stream.

Dissolved Air in Icebergs.

I had occasion to examine in some detail ice from an iceberg, and I was surprised to find what a large quantity of air is given off when it melts. The effervescence from the ice is quite apparent when floating in water. One iceberg was passed which was hissing like a pot of boiling water, and small pieces of ice were being cast off from it. I have thought since this observation that possibly the sudden disintegration of icebergs may be hastened by the pressure of the pent up air inside.

In the formation of the iceberg by great pressure from the Greenland glaciers, the air pressed down by the masses of accumulating snow is dissolved in the ice. The enormous pressure would increase the dissolving power of the ice. When the iceberg melts this air tends to come out, and forms innumerable bubbles which give the iceberg surface the white appearance.

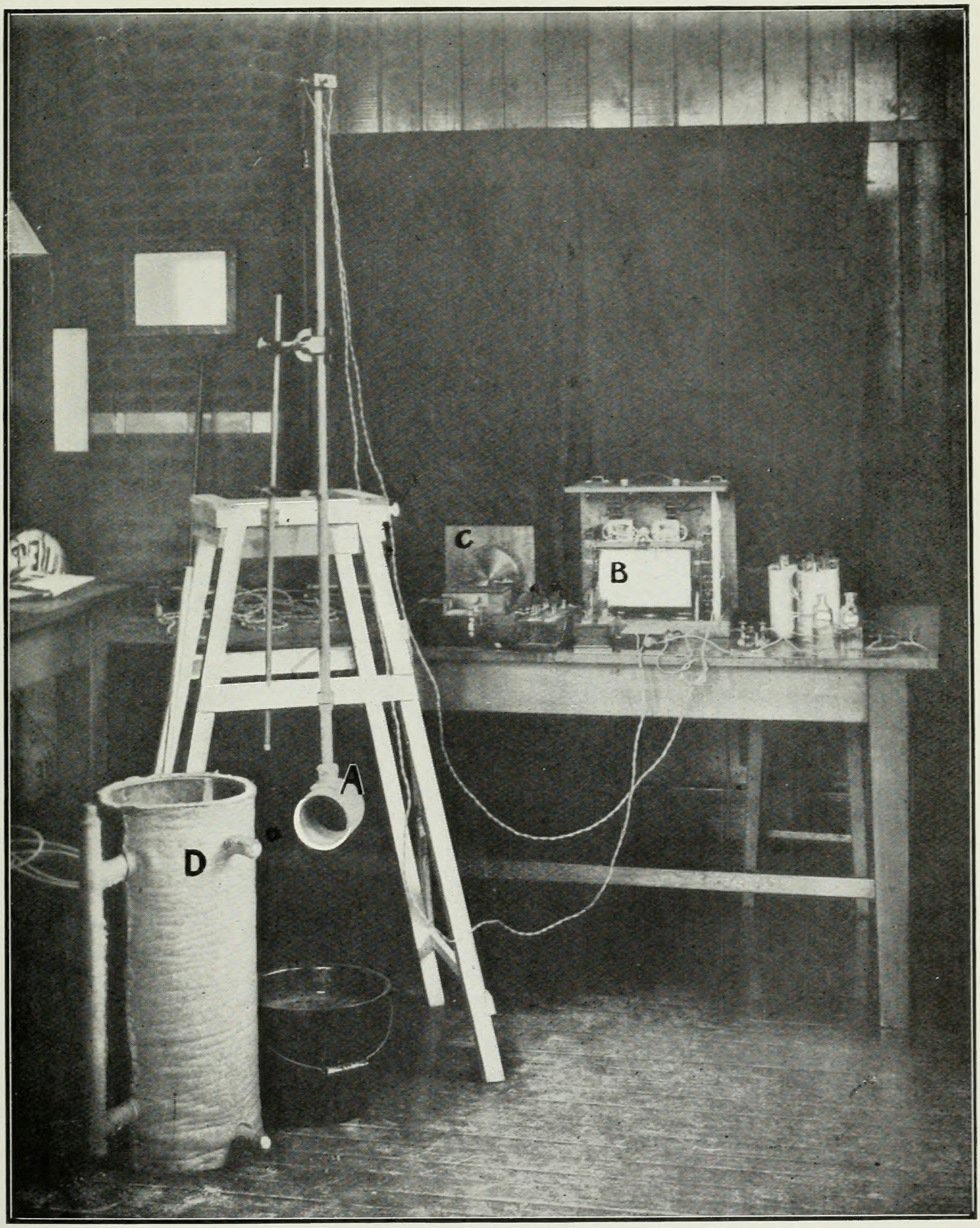


Fig. 26.- Microthermometer used in the tests. A represents the bulb, B the recorder, C the special relay and D the testing vessel for calibration.